Beam Power Tubes

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My introduction to beam power tubes came in the winter of 1951-52 when I built my first transmitter on a 7" x 9" open chassis with a fiberboard panel. It was a cathode-keyed tuned-plate power oscillator using a 6L6. There was a second tube on the chassis– a 5Y3GT with a power transformer salvaged from a junked television set. The rectifier worked half-wave with both plates in parallel into a capacitor-input filter. Good thing none of my neighbors had TVs – they could have read my call sign on their screens!

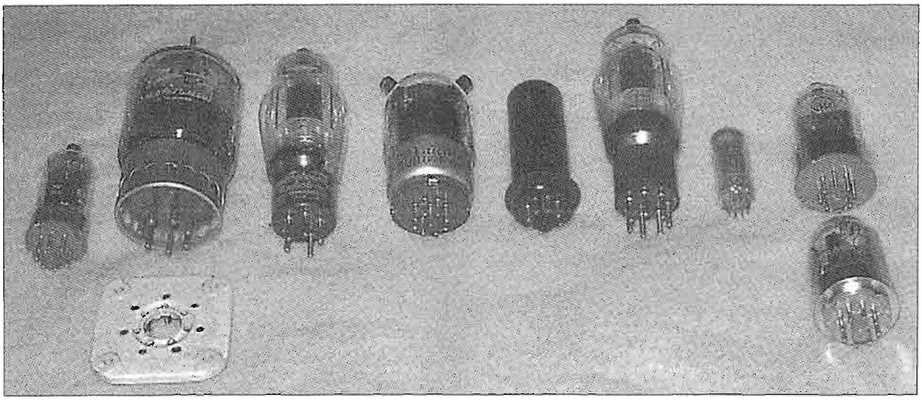
The design was based on one from a prewar ARRL Handbook that had been built on a breadboard. It wouldn't oscillate on the steel chassis, so I opened the grid leak and shorted the screen and cathode resistors. I had nothing left but the crystal, the tube and the plate tank circuit. At 600 VDC I dipped that tube to 125 MA at resonance. I was running 75 watts into a tube rated 30w maximum by the manufacturer!

The 6L6 only lasted for about 10 minutes of key-down, enough for an hour or two of operating. Then I had to use the folded up hand towel I kept handy to pull the tube out, and plug in another. But they were cheap. They were used as audio output tubes on large broadcast/shortwave radios. After a few years they got gassy and started to hiss at the listeners. The sets came back to the shop; the technician replaced the 6L6s and threw out the old ones. I scrounged my tubes from the shop trash bins after school. I did have to pay for replacement 5Y3s, though, when I transmitted too long and the plates turned red and sagged against the filaments.

The 6L6 was the first of the beam power tubes, announced by RCA in late 1935. It was intended as a replacement for the type 45 power pentode audio output tube, but by midyear 1936 it began to appear in RF circuits in QST. The June issue featured a 6L6 crystal oscillator, July a high fidelity amplifier, and September had a tri-tet oscillator and frequency multiplier. The 1937 ARRL book "Building an Amateur Radiotelephone Transmitter" showed 6L6s as push-pull modulators. The tube sold at that time for 98 cents.

By late 1936, RCA was selling the first beam power tube designed especially for transmitter service, the 807, initially rated 40w input but increased within a year to 60w. At only $3.90 its cost was well below that of comparable ordinary transmitting tubes. Not much later Raytheon offered the RK-39, also rated 40w. In January 1937, Ken-Rad announced the 4.25w 6V6 as an auto radio audio output tube, and RCA introduced the 2w 25L6 for the same service in series-string ac-dc radios. In July 1937 Raytheon brought out the 375w (120w out) RK-47 and 800w (250w out) RK-48 transmitting tubes. By January 1938 RCA, not to be outdone, announced the 450w (160w out) 814 and 800w (375w out) 813.

After that came a veritable flood of beam power tubes. The 35L6 and 50L6 joined the 25L6 to avoid using a ballast resistor in different tube lineups. The 35L7 and 50L7 combined a beam power tube with a rectifier diode in the same octal-base package. The 7A5 was rated 1.9w with a loctal base. After the war the 35C5 and 50C5 contained a 4.5w beam power tube inside a 7-pin minia-



Here are some examples of transmitting type beam power tubes. From left to right: Raytheon 2E26, Eimac 4E27A/5-125B above an EF Johnson forced-air cooling socket, Westinghouse 807, RCA 815, RCA 1622, RCA 1625, RCA 5763, RCA 6146 which is above a Sylvania 6146B.

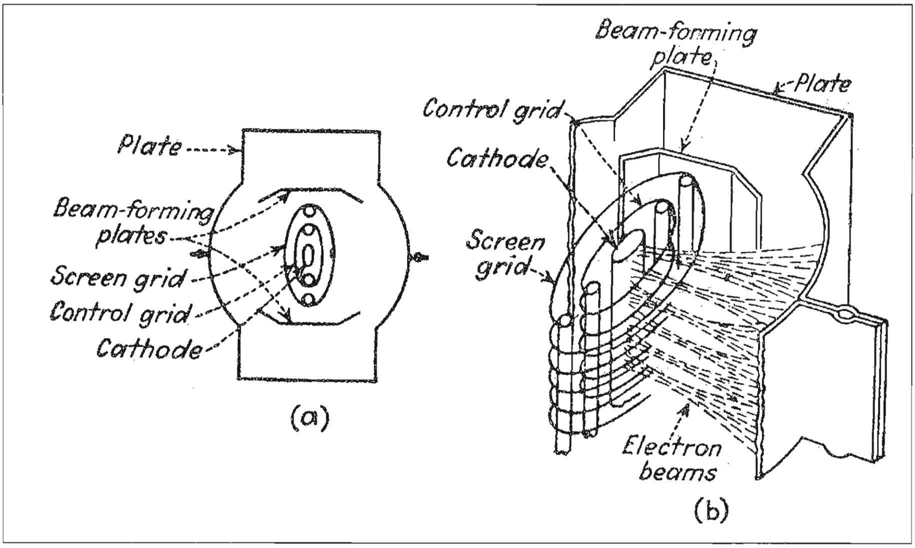
ture envelope. The 5763 was a 9-pin miniature with a huge 17 watts input. The 2E24 and 2E26 handled 40 watts at VHF frequencies and the 90w 6146, an improved version of the 75w 807, worked up there as well. Later, the 6146B did it with 120w into its plate.

Why did the beam power tube so suddenly and completely take over so many vacuum tube functions? There are two main reasons, the first of which is called power sensitivity. The beam power design simply added beam-forming plates to the basic power tetrode/pentode design. These plates are mounted at the ends of the grids, just beyond the posts that support them. The plates are held at cathode potential, thus focusing the electrons that would otherwise escape at the ends of the grids back to the anode plate of the tube. This greatly increased the electron density at the plate, thus allowing a much greater power output for a given power input. Beam power tubes are not much better as voltage amplifiers than ordinary power tubes, but they are excellent power amplifiers. And this also lets them operate at a much lower plate voltage than comparable ordinary tubes.

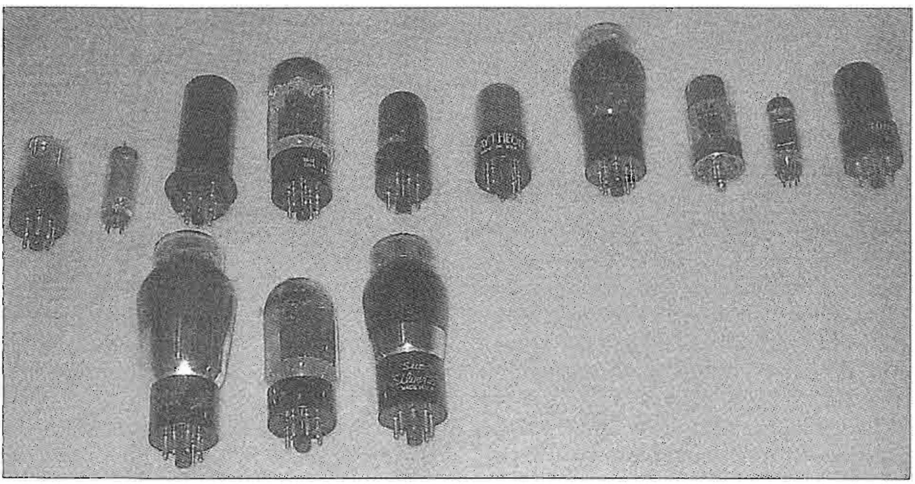
Second, the fact that almost all the electrons that are given off by the cathode pass the control grid and go directly to the plate, which makes for greatly improved linearity. A beam power tube has virtually no re-emission or reflection of electrons from the plate. The solid-state people have not, to this day, developed any device that can handle high power with the linearity of a beam power tube. That is why both today's high fidelity audio fan and popular musician still prefer amplifiers with beam power tubes.

There are many additional advantages to this design. For example, the minimal loss of electrons means that there are few available for heating the glass bulb even without getters or other means of mopping up stray electrons. This means that the glass remains relatively undamaged, minimizing gas leakage into the vacuum. Similar minimization of internal damage to tube elements also helps to prolong tube life. Thus, actual tubes retain their theoretical characteristics much longer. This helps explain why my power oscillator tube could survive as well as it did, given the rather brutally excessive power I drove through it.

Other advantages include minimal effective interelectrode capacitance due



In this figure, a horizontal cross section of a beam power tube is shown in (a), and a cut-away view of a 6L6 tube is shown in (b), which clearly shows the electron beams as they are formed by the grid structure and the two beam-forming plates. By confining the electron beam in this manner, a "virtual cathode" forms between the screen grid and plate that prevents secondary emission, and also reduces screen-grid current. (from Eastman, Fundamentals of Vacuum Tubes, McGraw-Hill 1941)



Beam power receiving tubes were also quite common, and here are some examples. From left to right are a Sylvania 3Q5GT, GE 6AQ6A, NU 6L6 which is above a Sylvania 6L6G, GE 6L6GB above an RCA 6L6GC, a Tung-Sol 6V6GT above a Silvertone 6V6G, a Raytheon 6W6GT, a CBS-Hytron 6Y6G, a Raytheon 7A5, a CBS 50C5 and lastly a Tung-Sol 50L6GT.

to the heavy space charge near the plate. Beam power tubes thus require little if any neutralization. When neutralization is required, it is very noncritical and thus easy to adjust and doesn't need frequent readjustment. Also, this means that the plate is a true anode. Design of the plate is about the only factor controlling the power handling ability of the tube, as witnessed by the 5763. Minimal electron losses means maximum efficiency; thus a very powerful tube be can fitted into a very small package.

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Typical Beam Power Tube Specifications -

Type	Cathode Volts	Amps	Plate Volts	Input Watts	Output Watts	Max MHz	Notes (Octal base unless noted)
1T5GT	1.4	0.05	90	0.17			portable radios
3Q5GT	2.7ct	0.05	90	0.27			portable radios
35A5	35.0	0.16	110	1.4			
70A7GT	70.0	0.15	110	1.5			+ 125v 60ma diode rect, ac-dc radios
32L7GT	32.5	0.3	110	1.5			+ 125v 60ma diode rect, ac-dc radios
35L6G	35.0	0.15	110	1.5			ac-dc radios
70L7G	70.0	0.15	110	1.8			+ 125v 70ma diode rect, ac-dc radios
7A5	7.0	0.75	125	1.9			Loctal base
25L6	25.0	1.25	110	2.2			ac-dc radios
50L6GT	50.0	0.15	110	2.2			ac-dc radios
6W6GT	6.3	1.25	135	3.3			
6Y6G	6.3	1.25	135	3.6			
6AQ5A	6.3	0.45	275	4			7-pin Miniature base
6V6	6.3	0.45	300	4.25			
35C5	35.0	0.15	110	4.5			7-pin Miniature base
50C5	50.0	0.15	110	4.5			7-pin Miniature base
6AS5	6.3	0.8	150	5.4			7-pin Miniature base
25C6G	25.0	0.3	200	6			ac-dc radios
1622	6.3	0.9	300	10			
5763	6.3	0.75	350	17	12	50	9-pin Miniature base
6L6/6L6G	6.3	0.9	375	33	17		also KT66, KT88 & 5881
2E24	6.3	0.65	600	40	27	125	
2E26	12.6ct	0.4	600	40	27	125	6893 is 12.6v
1624	2.5	2.0	600	54	35		5-pin Medium base
RK41	2.5	2.4	600	56	36		5-pin Medium base, RK39 is 6.3v
807	6.3	0.9	750	75	50	60	5-pin Medium, also 807W & 5933
1625	12.6	0.45	750	75	50	60	7-pin Medium base
815	12.6ct	0.8	500	75	50	125	dual tube working push-pull
6146/6146A	6.3	1.25	750	90	70	60	8032 & 6883 are 12.6v, 6159B 26.5v
6146B/8298A	6.3	1.125	750	120	85	60	
4636				300		890	
8226				340		400	or 105w to 1215MHz
RK47	10.0	3.25	1250	375	120		5-pin Medium base
814	10.0	3.25	1500	450	160	30	5-pin Medium base
4E27A/5-125B	5.0	6.5	3000	500	375	75	7-pin Medium base w/forced-air hole
RK48	10.0	5.0	2000	800	250		5-pin Jumbo base
813	10.0	5.0	2000	800	375	30	7-pin Jumbo base
8977			8400	5kw			broadcast TV audio final amp
9007			8400	27kw			broadcast TV video final amp
4CX7500A							Svetlana ceramic TV final amp

Note – Different reference materials show different specs. I tried to use those from the period when each type was at the peak of its popularity for amateur service.